NOTES ON THE PHYSIOGRAPHY OF NORTH DAKOTA AND THE CONDITIONS IN CERTAIN OF ITS WATERS

R. T. YOUNG

Professor of Zoology, University of North Dakota,
Director of Biological Station, Devils Lake, North Dakota

The following notes on the physiography of North Dakota and the conditions in certain of its waters are intended as an introduction to the paper by Dr. Moore and Dr. Carter on the plankton algae of these waters.

North Dakota may be divided into three main areas: (1) the Red River Valley, occupying the basin of glacial Lake Agassiz; (2) the drift prairie plain, a region covered with glacial till and boulders and of irregular surface, which slopes gradually upward from the valley to (3) the Missouri Plateau, an elevated tableland occupying the southwestern half of the state. The latter area is deeply cut by the valley of the Missouri River, a little to the east of which, and running nearly parallel with it, is an irregular line of low hills, constituting the Altamont Moraine, which marks the southwestern edge of the glacier which in the last glacial epoch covered the eastern half of the state, and whose drainage, in its retreat, formed Lakes Agassiz, Souris, and Saskatchewan. Southwest of the Missouri River is the greatly eroded region known as the "badlands," which constitutes the most picturesque feature of the state.

In the northern part of the area, on the Canadian boundary, is a group of low, irregular hills constituting the Turtle Mountains. These hills rise from 120 to 180 meters above the surrounding plain, and represent a portion of the Missouri Plateau, isolated therefrom by erosion, prior to the advent of the glaciers, and covered by the latter with till to a depth of from 30 to 60 meters. Among these hills are numerous spring-fed, freshwater lakes, the largest of which, just east of Bottineau, has an area of about 6 square kilometers.

Between the Turtle Mountains and the Missouri Plateau lies the broad flat plain of the Mouse River occupying the basin of the glacial Lake Souris which extended northward into Canada.

The lakes considered in the present report are found in the drift prairie plain and Turtle Mountains. The drainage of the areas is very poor and numerous depressions among the hills form the basins of many of the lakes. While most of them are merely depressions in the land filled with water, there are several which are either expansions of an existent river near its headwaters, or which occupy portions of an old river channel. The largest of these are Devils Lake and Stump Lake, which were at one time parts of the much larger glacial Lake Minnewaukon, draining into the Sheyenne River.

Another group of these lakes is found in the course of the James River, north of Jamestown, and comprises Arrowhead, Jim, and one or two smaller lakes.

Spiritwood I and II and a number of neighboring lakes probably occupy an old river valley and the same is very evident in the case of Strawberry, Long, Crooked, and Turtle Lakes, north of Washburn.

Most of the lakes are shallow, having a depth of not more than 3–4.5 meters, while many are merely shallow pools which dry up in dry years, but may have a considerable extent in years of heavy rainfall. The deepest of any is Alkali Lake, II, which has a maximum depth of 27 meters. Their supply comes partly from springs, partly from run-off of rain or melting snow. In most cases this supply is inadequate to meet the demand and the lakes are gradually drying up. This is notably true of such highly alkaline bodies as Devils and Stump Lakes, but even in the case of spring-fed, freshwater lakes in the Turtle Mountains there has been a marked decrease in level in recent years. This drop may be due in part to the general lowering of the water table throughout the state in recent years, which in turn is probably due to continued opening of new artesian wells and their uncontrolled flow.

Most of the lakes under consideration have no outlet and this, coupled with their decrease in level in many instances, has led to the high concentration of salts present in so many of them.

Where the lakes have an outlet, either permanently or at times of high water only, as in the case of Arrowhead and Jim Lakes, already mentioned, the salts washed into the lakes by run-off from the drainage area are carried out by the outflow. In the case of lakes which are completely land-locked but yet are not markedly alkaline, it is probable that acids carried in by run-off from humus-covered areas, neutralize the alkalies in the water and largely precipitate them in the form of insoluble salts. The presence of organisms in the water, especially animals, may play a small part in reducing alkalinity through the production of carbon dioxide.

With reference to their chemical character it is not possible to make any definite classification of the lakes. They range all the way from those of a distinctly freshwater type, with low alkalinities, to exceedingly brackish waters with total carbonate alkalinities running up to 2000 ppm. and more.

But little attention has been paid to physical features, such as temperature, turbidity, and color, in most cases. Where the lakes are shallow there is little temperature difference between surface and bottom, and the summer temperature frequently runs up to 25° C. or more, especially near shore. In the deeper lakes several degrees difference may exist between surface and bottom. The determinations, however, in most of the lakes are too few to permit of any generalizations.

The larger plants comprise chiefly *Ruppia maritima*, which occurs abundantly in practically all the lakes of the region; *Potamogeton*, *Myriophyllum*, *Ceratophyllum* and *Chara*, all of which are common in fresh water; while *Juncus*, *Carex*, and *Scirpus* are abundant in the shallower parts of all but the more alkaline lakes.

The location of each lake is indicated on the accompanying map (pl. 20). In considering the various lakes, no definite classification can be made, either in the character of the water, or in the nature of shores and bottom. Several of the freshwater lakes, especially such as are merely expansions of a river, are very shallow, largely overgrown with rushes and sedges, and with muddy bottoms. Others, such as Spiritwood and Wood Lake, have, in part, rocky, steeply sloping shores with comparatively free water close to shore, while in other parts the shores may be gently sloping, with sandy or muddy bottom, and largely overgrown with rushes, sedges, and pond-weeds of various sorts. The alkaline lakes in general lack the abundant growths of these plants, but their place is largely taken by *Ruppia* and the bottom is more apt to be covered by fine black ooze, the result of accumulation of large amounts of wind-borne dust and decaying plant and animal life. Both phyto- and zoo-plankton are generally abundant in all of the lakes, especially the former, which frequently forms a "water-bloom" on the surface.

The lakes may be grouped roughly into (1) freshwater, those with total alkalinities below 400 ppm., (2) intermediate, with alkalinities between 400 and 700 ppm., and (3) alkaline lakes with alkalinities above 700.

(1) Freshwater lakes. Here may be included those in the Turtle Mountains (Carpenter, Crow, Dion, Fish, Gravel, Gordon, Jarves, Metigosche, and Willow), and those in the James River Valley (Arrowhead and Jim Lakes), Court, Crooked, Ensign, near Frettem, Fort Totten, Juanita, Long Lake, near Ruso, Painted Woods, Red Willow, near Binford, Spiritwood I and II, Strawberry, South Twin (Lake Y) and Wood Lakes, besides a few others, which are mere ponds formed by the outflow of springs (Cut-off, Eastgate's, and Wheeler's Ponds I and II, near Stump Lake, and ponds H and I at the Odessa Narrows).

(2) Intermediate Lakes. Blue, Brush, Clear, Florence, Long Lake, near Binford, Sweetwater, South Free Peoples, Williams, and X.

(3) Alkaline lakes are those of the Devils-Stump Lake complex, including Main, East, Lamoreau, Stump, Mission, and Spring Lakes, and Lakes A, C, N[1], O[1] and P, besides Alkaline Lakes I and II, Buffalo, Coe, Etta, Four-Mile, North Free Peoples, Isabelle, Tokio, Twin, North and South Washington Lakes, Lake Z, and the ponds south and southwest of Brush Lake.

For most of the lakes only alkalinities have been determined. Of several, however, general analyses have been made. Three of

[1] These are temporary pools formed by rain and melting snow, occupying depressions in the floor of the old Devils Lake. Consequently they vary greatly from time to time.

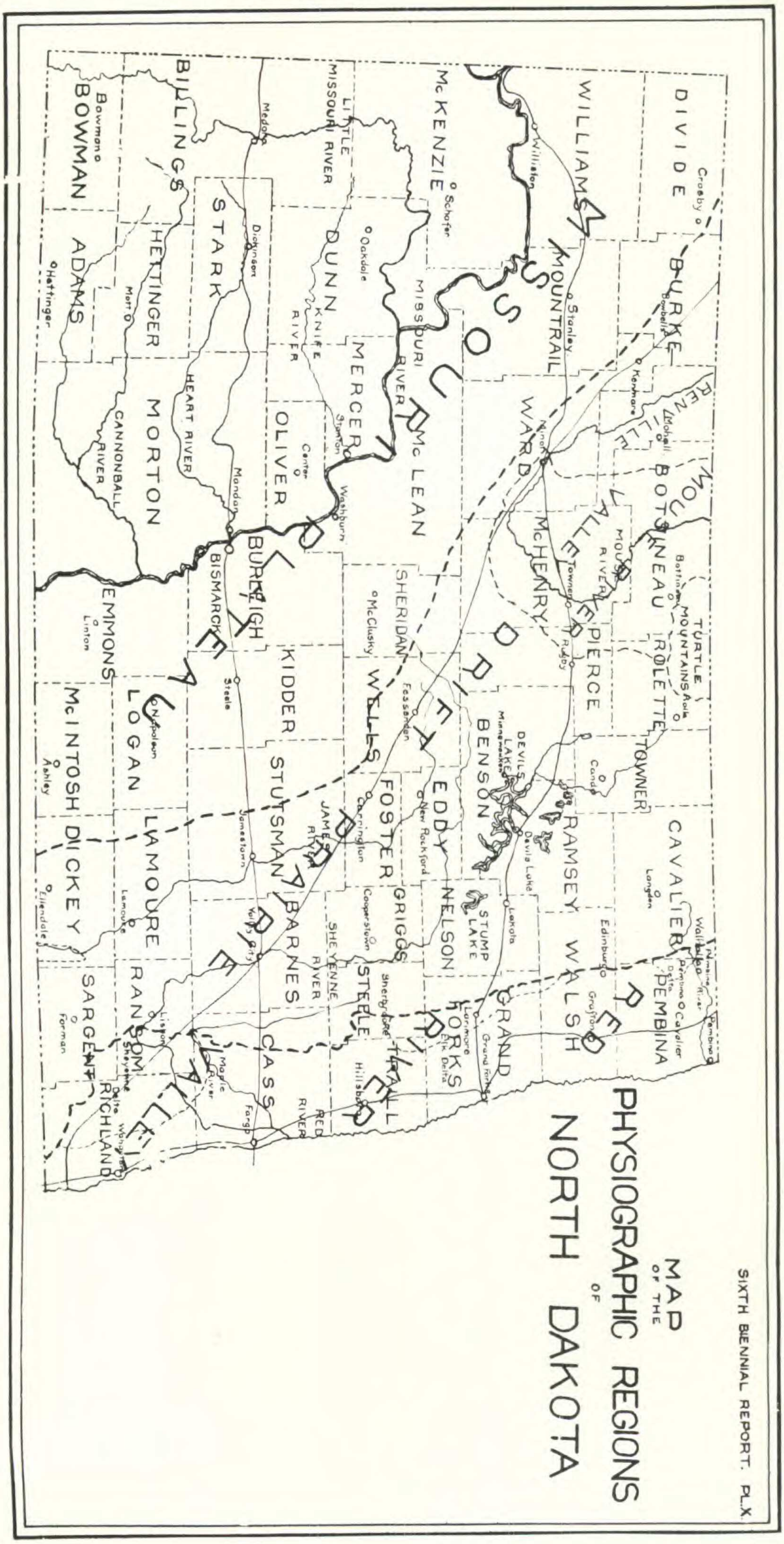
them, which are fairly representative of the three classes into which the lakes under discussion have been grouped, are given in the accompanying table.

Source	CO_3	HCO_3	Cl	SO_4	Mg	Ca	Na	K	SiO_2	Fe_2O_3 and Al_2O_3	Residue
Ft. Totten Lake (1919)	60	15	10	166	27	34	31	5	Trace	Trace	386
Sweetwater Lake (1911)	—	496.5	10.0	177.7	45.8	162.1	13.9	.1	17.0	2.0	694.0
Devils Lake (1919)	305	458	131 0	7187	585	70	2548	204	62	95	13462

Explanation of Plate

PLATE 19

Map of the physiographic regions of North Dakota (from the sixth biennial report of the North Dakota Geological Survey. Courtesy of Dr. A. G. Leonard, Director).



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Explanation of Plate

PLATE 20

Map of northeastern part of North Dakota (drawn by Wilfred C. Lowe).